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THE EVIDENCE OF THE FLORA REGARDING THE AGE OF THE RARITAN FORMATION

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Since it has been supposed by some invertebrate paleontologists that the Atlantic and Eastern Gulf Cretaceous above the Patapsco formation of the Maryland-Virginia area is all of post-Colorado age, i.e., Senonian by European standards, and since the faunas are for the most part poorly preserved and but partially studied, and furthermore since the physical conditions were more uniform than in the great plains area as indicated by the character of the sediments and strongly emphasized by the faunas, the following conclusions based upon a critical study of the Raritan flora may prove of interest to geologists since they clearly indicate that this flora when judged by European standards cannot be considered younger than the Turonian, while a strong case can be made out for its Cenomanian age. Furthermore when judged by American standards it is most decidedly pre-Montana in character.

No attempt is made to make the following brief article polemical in character, and hence arguments which might be drawn from stratigraphy and paleozoölogy are not mentioned, it being the desire of the writer to place a brief statement of the paleobotanical evidence before the public.

The following pages form part of a systematic report on the flora of the Raritan formation in New Jersey prepared over a year ago and to be published by the Geological Survey of that state, and the writer is indebted to the kindness of Dr. Henry B. Kümmel, the state geologist, for permission to publish them in advance of the complete report.

Passing over the somewhat diverse views of the older writers who were inclined to regard the Raritan as of Jurassic age,¹ we find Professor

¹ This age was also claimed for it by the late Professor O. C. Marsh in several papers published a score of years ago.

J. S. Newberry, in 1890, recognizing the Amboy Clays as Cenomanian in age and synchronous with the Dakota Group of the West. Professor Lester F. Ward was the first to point out that the Raritan was older than the Dakota Group, which is undoubtedly the case, and it has been customary in recent years to follow the latter author and regard the former as roughly corresponding to the Gault of England and the Albian of continental Europe. The view here presented is that the Raritan flora is much more closely allied with the Cenomanian of the Old World than it is with the Albian or Gault. At the same time it is quite obviously older than the Magothy flora, that of the Dakota Group, and those of the South Atlantic Coastal Plain,¹ so that if these latter are to be considered of Cenomanian age they are to be regarded as Upper Cenomanian while the Raritan is to be regarded as Lower Cenomanian. European geology furnishes a similar case in the division of the Cenomanian into the substages Rotomagian and Caretonian, although probably the parallelism of substages cannot be carried across the ocean. European paleontology furnishes abundant and well-characterized Cenomanian and Senonian floras for comparison and by this standard the Raritan as well as the somewhat younger Dakota and Magothy floras are clearly Cenomanian floras. The Turonian stage of European geology on the other hand has thus far yielded so meager a flora that it is practically useless as a basis for comparison and it may well be that the flora of the Dakota Group along with its southern and eastern representatives—the Woodbine, Tuscaloosa, Eutaw, Black Creek, Middendorf, and Magothy floras—represents the Turonian stage of Europe. Stratigraphically there is no contrary evidence and the Dakota sandstone would simple go with the overlying Benton which invertebrate paleontologists have long considered as representing the Turonian.

The paleobotanical evidence for the Cenomanian age of the Raritan formation is briefly as follows. On general grounds we find the Raritan flora more complex and modern in its composition than any known Albian flora; for example, dicotyledons make up 68 per cent. of the Raritan flora while not a single dicotyledon is known from the English Gault and the representation of this group of plants in the

¹ Older Cretaceous deposits are known from North Carolina to Alabama, but these are, so far as known, unfossiliferous.

Albian of France and Portugal is very meager indeed and comparable to the display of these plants in the Patapsco formation of Maryland and Virginia, the latter showing a striking parallelism with the Albian of the Old World with at least one identical species and closely allied representatives in several identical genera.

Species which are peculiar to the Raritan formation number 51 as follows:

<i>Acer amboyense</i> Newb.	<i>Laurophyllum lanceolatum</i> Newb.
<i>Aralia patens</i> Holl.	<i>Laurophyllum minus</i> Newb.
<i>Aralia rotundiloba</i> Newb.	<i>Leguminosites raritanensis</i> Berry
<i>Asplenium raritanensis</i> Berry	<i>Liriodendron quercifolium</i> Newb.
<i>Bauhinia gigantea</i> Newb.	<i>Menspermites wardianus</i> Holl.
<i>Caesalpinia cookiana</i> Holl.	<i>Myrica acuta</i> Holl.
<i>Caesalpinia raritanensis</i> Berry	<i>Myrica cinnamomifolia</i> Newb.
<i>Calycites diospyriiformis</i> Newb.	<i>Myrica jenestrata</i> Newb.
<i>Calycites parvus</i> Newb.	<i>Myrica hollicki</i> Ward
<i>Carpolithus ovaeformis</i> Newb.	<i>Myrica Newberryana</i> Holl.
<i>Carpolithus pruniiformis</i> Newb.	<i>Myrica raritanensis</i> Holl.
<i>Carpolithus woodbridgensis</i> Newb.	<i>Myrsine oblongata</i> Holl.
<i>Celastrophyllum grandifolium</i> Newb.	<i>Newberryana rigida</i> (N.) Berry
<i>Celastrophyllum minus</i> Holl.	<i>Passiflora antiqua</i> Newb.
<i>Celastrophyllum spatulatum</i> Newb.	<i>Phyllites undulatus</i> Newb.
<i>Chondrites flexuosus</i> Newb.	<i>Planera knowltoniana</i> Holl.
<i>Chondrophyllum obovatum</i> Newb.	<i>Persoonia spatulata</i> Holl.
<i>Chondrophyllum reticulatum</i> Newb.	<i>Podozamites acuminatus</i> Holl.
<i>Cornophyllum vetustum</i> Newb.	<i>Populus orbicularis</i> (Newb.) Berry
<i>Dewalquea trifoliata</i> Newb.	<i>Protophyllum obovatum</i> Newb.
<i>Diospyros raritanensis</i> Berry	<i>Prunus</i> (?) <i>acutifolia</i> Newb.
<i>Eucalyptus parvifolia</i> Newb.	<i>Rhamnites minor</i> Holl.
<i>Fontainea grandifolia</i> Newb.	<i>Salix pseudo-hayei</i> Berry
<i>Hedera obliqua</i> Newb.	<i>Sphaerites raritanensis</i> Berry
<i>Ilex elongata</i> Newb.	<i>Williamsonia smockii</i> Newb.
<i>Ilex amboyensis</i> Berry	

Obviously these are of little service in correlation; nevertheless all but one or two are dicotyledons of genera which in Europe are found in the Cenomanian, Turonian, and Senonian. Allied forms are largely represented in the Magothy formation, the Dakota Group, and the Atane beds of Greenland.

There are eleven Lower Cretaceous species which persist into the Raritan. These are:

<i>Asplenium dicksonianum</i> Heer	<i>Gleichenia zippei</i> Heer
<i>Celastrophyllum brittonianum</i> Hollick	<i>Podozamites knowltoni</i> Berry
<i>Ficus myricoides</i> Hollick	<i>Podozamites lanceolatus</i> (L. & H.) F.
<i>Frenelopsis hoheneggeri</i> (Ettings.) Schenk	Braun
<i>Gleichenia giesekiana</i> Heer	<i>Sequoia reichenbachii</i> (Gein.) Heer
<i>Gleichenia micromera</i> Heer	<i>Thuyites meriani</i> Heer

Of these the ferns and the gymnosperms which make up the bulk of the list are to be regarded primarily as Lower Cretaceous types which survived into the Upper Cretaceous, while the dicotyledons are precursors of the Upper Cretaceous flora. Among the generic types of ancient lineage which are represented in the Raritan are *Baiera*, primarily a Triassic and Jurassic genus the Raritan species of which is closely related to forms found in the Older Potomac, *Williamsonia*, a Jurassic and Lower Cretaceous genus, *Brachyphyllum*, a Triassic and Jurassic genus the Raritan species of which is closely related to, and clearly descended from, *Brachyphyllum crassicaule* Font. of the Patapsco formation, and finally *Czekanowskia*, a Triassic and Jurassic (chiefly Oölitic) genus.

In no part of the world has a single representative of any of these genera been found as late as the Senonian and it is significant that two of them, *Brachyphyllum*¹ and *Czekanowskia*, furnish their last known record in the Cenomanian of Portugal while the last occurrence of *Baiera* and *Williamsonia*² is in the Cenomanian Atane beds of Greenland.

When the Raritan flora is compared in detail with the Patapsco flora of Maryland and Virginia many common features are brought out which at first sight tend to be obscured by the preponderating dicotyledonous element in the former. In addition to the identical or closely related forms previously mentioned we find among the dicotyledons nine Raritan genera which make their first appearance in the Patapsco. These are *Aralia*, *Sassafras*, *Celastrophyllum*,

¹ The Raritan species *B. macrocarpum* Newb. is recorded from the following American horizons: Montana Group of Wyoming, Dakota Group of Kansas, Magothy formation of Long Island, New Jersey, and Delaware, the Middendorf of South Carolina (?), the Black Creek of North Carolina, the Tuscaloosa and Eutaw of Alabama, and the Patoot beds of Greenland (?), the former of course of Senonian age.

² A questionable species is recorded from the Dakota Group and another species occurs in the Magothy formation.

Cissites, Sterculia, Quercus, Populus, Eucalyptus, and Ficus. The genus *Celastrorhynchium* with a large display of forms in both the Patapsco and the Raritan has one identical species, *C. brittonianum* Hollick, while *C. hunteri* of the former is very close and ancestral if not actually identical with *C. angustifolium* Newb. of the latter. Eucalyptus has closely related species at both horizons while Ficus has a common species, *F. myricoides* Hollick, in both formations.

Among the conifers the widespread *Widdringtonites ramosus* (Font.) Berry of the Patapsco is closely related to, if not identical with, the equally common *Widdringtonites reichii* (Ettings.) Heer of the Raritan and succeeding formations. The genus *Frenelopsis* has closely related species in both while *Sequoia* and *Thuja* have already been mentioned as well as the cycadean genus *Podozamites* which ranges back to the Triassic. Two Raritan species are recorded from the European Albion. These are *Sequoia reichenbachii* (Gein.) Heer and *Eucalyptus arguta* Velen., the former a very wide-ranging form and the latter recorded from the Albion of Portugal and the Cenomanian of Bohemia.

Turning to the elements in the Raritan flora which ally it with younger floras, we find that six of the Raritan species persist as late as the Senonian of Europe and fifteen are found in the Patoot beds of Greenland which are also usually regarded as of Senonian age. All but four of the latter are, however, found in the Cenomanian beds of that country and practically all of the others and those common to the Senonian of Europe as well occur somewhere in Cenomanian strata. There are thirty-four species common to the Raritan flora and that of the Dakota Group,¹ the former lacking more particularly the numerous forms of *Betula*, *Quercus*, *Platanus*, etc., which characterize the latter. There are 32 species common to the Raritan and to the Atane beds of Greenland, the latter formation being usually regarded as Cenomanian in age, and there are sixty-seven species common to the Raritan and Magothy floras, although these latter figures are somewhat obscured by the difficulty of determining the probable age of many of the species recorded from Long Island and other areas in the vicinity of the terminal moraine and by the additional

¹ This statement applies only to New Jersey forms and is intensified if the supposed Raritan of Staten Island and Long Island is included.

fact that the Upper Raritan at South Amboy, N.J., furnished many of these identical species and it is quite likely that some of the species credited to South Amboy on the authority of Professor Newberry and not since collected may really have come from within the Magothy formation, since the Morgan locality which is of Magothy age would not have been kept distinct from South Amboy as a place-name in Professor Newberry's day.

The known Montana Group flora, the published accounts of which, by Dr. F. H. Knowlton, are contained in *Bulletins* 163 and 257 of the U.S. Geological Survey, embraces over one hundred species of which six are common to earlier horizons, two to the flora of the Dakota Group, and five to that of the Raritan, all being pre-Senonian survivors. One of these, *Sequoia reichenbachii*, ranges from the base to the summit of the Cretaceous and hence possesses no significance, and another, *Sequoia heterophylla*, ranges up into the Senonian of Europe. On the other hand not one of the characteristic Senonian (Montana) species occurs in the Raritan and there are twenty-seven Montana genera which are not even represented in the Raritan flora. Not one of the eleven Lower Cretaceous species which persist into the Raritan of the East are found in the Montana flora, although similar Lower Cretaceous floras are known from the Trinity of Texas, the Kootanie of Montana and Canada, the Lakota of the Black Hills, and the Shasta of California. If they survive in the East until Montana time, as has been asserted, why not at some other point on the earth's surface where conditions must have been equally favorable? Furthermore, the characteristic genera of the Raritan flora, such as *Aralia*, *Sassafras*, *Celastrorhynchium*, *Eucalyptus*, *Sterculia*, *Cissites*, etc., are entirely unrepresented in the Montana flora, which has a totally different and more modern facies and the genera which are common to the two horizons, such as *Myrica*, *Magnolia*, *Ficus*, etc., have an entirely different set of species.

In conclusion it should be pointed out that the Raritan flora as developed in New Jersey includes over 150 species which are for the most part well preserved and abundantly represented. In striking contrast with this representative flora the supposed Raritan fauna comprises a species of *Astarte*, one of *Ambocardia*, one of *Rangia* (?), two of *Corbicula*, one of *Corbula*, one of *Turritella*, and one of *Cym-*

bophora, the two latter marine and specifically unidentifiable and the six former brackish in type and of doubtful generic relations.

Dr. Stuart Weller in his admirable investigation of the New Jersey Cretaceous did not actually collect any of these forms and all are based on single occurrences mostly of ancient date made when the importance of definiteness regarding exact localities was not appreciated. None have been subsequently collected, although the number of openings in this area is very great; the region is visited annually by numerous geological students and it is a common practice for the workmen to save unusual objects such as fossils which they find and these usually find their way into the hands of collectors visiting the clay-pits.

The *Astarte* is listed on the authority of Conrad, the *Ambocardia*, *Rangia*, and the two *Corbiculas* on the authority of Whitfield, and the *Turritella* and *Cymbophora* on the evidence of a single slab of sandstone in the State Survey collection obtained over twenty-five years ago and said to have come from Sayreville. It will be obvious that evidence of so scanty and indecisive a character is hardly to be given much weight.

CONCLUSIONS

1. The Raritan flora is clearly shown to be of Upper Cretaceous age.
2. It is shown to be very similar to, but somewhat older than, the flora of the Dakota Group, and to be identical with widely scattered floras usually regarded as of Cenomanian age.
3. It is shown to be totally distinct from the known flora of the Montana Group.

¹ Weller, *Geol. Surv. of N.J., Paleont.*, IV (1907), 28.